ASSESSING TNT TOXICITY IN SOILS WITH CONTRASTING CHARACTERISTICS USING SOIL INVERTEBRATE TOXICITY TESTS

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ABSTRACT

We investigated the toxicity of 2,4,6-trinitrotoluene (TNT) to earthworm (*Eisenia fetida*), potworm (*Enchytraeus crypticus*), and springtail (*Folsomia candida*) in five natural soils: Sassafras sandy loam (SSL), Teller sandy loam (TSL), Richfield clay loam (RCL), Kirkland clay loam (KCL), and Webster clay loam (WCL). According to Ecological Soil Screening Level (Eco-SSL) criteria (USEPA 2003), relative bioavailability scores for organic chemicals in these soils were rated “high” for SSL and TSL, “medium” for RCL and KCL, and “low” for WCL soil. We adapted standardized toxicity tests using soils that were either freshly amended (24 h) or subjected to wetting/drying cycles (10-14 weeks) after amendment to determine the effect of weathering/aging on TNT toxicity. We used nonlinear regression models to determine the EC_{20} and EC_{50} TNT concentrations for reproduction endpoints. Initial results for freshly amended soils showed that TNT toxicity to juvenile production of both *E. fetida* and *E. crypticus* was TSL > SSL > RCL > KCL > WCL. TNT toxicity to juvenile production of *F. candida* was TSL > SSL > KCL > RCL > WCL in freshly amended soils. TNT in WCL, with “low” relative bioavailability, was least toxic of the five soils tested. Toxicity benchmarks derived in these studies will be submitted to the Eco-SSL Task Group for use in developing an Eco-SSL for soil invertebrates and TNT; results of these studies will undergo quality assurance before inclusion in the national Eco-SSL database.

INTRODUCTION

Objective Force Soldiers must receive highly realistic training across the spectrum of military operations. Increased realistic training leads to increased releases of explosives into the environment at training sites. Concentrations of 2,4,6-trinitrotoluene (TNT) in soil have been reported to exceed 87,000 mg kg^{-1} (Simini et al., 1995). TNT contamination at these sites may therefore pose significant risk to DOD personnel and the surrounding environment. Examination of the toxic effects of TNT and related chemicals on soil organisms in different soil types will provide valuable information about the extent of environmental impact and potential food chain effects. Knowledge acquired from these studies will be used to quantify ecotoxicological benchmarks to develop Ecological Soil Screening Levels (Eco-SSLs). Eco-SSLs are derived from laboratory toxicity tests with different test species relevant to soil ecosystems (USEPA, 2003). These studies address existing data gaps, and establish ecotoxicological benchmarks that are necessary to derive a TNT Eco-SSL for soil invertebrates.

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METHODS

Five soils that differ in relative bioavailability for organic chemicals were amended with TNT. Adapted standardized toxicity tests were conducted using soils that were either freshly amended (24 h) or subjected to wetting/drying cycles (10-14 weeks) after amendment to determine the effect of weathering/aging on TNT toxicity. We included multiple, replicated treatment concentrations with negative, carrier (acetone), and positive controls. We used nonlinear regression models to determine the EC_{20} and EC_{50} TNT concentrations for reproduction endpoints.

RESULTS AND DISCUSSION

Initial results for freshly amended soils showed that TNT toxicity to juvenile production of both *E. fetida* and *E. crypticus* was TSL > SSL > RCL > KCL > WCL. TNT toxicity to juvenile production of *F. candida* was TSL > SSL > KCL > RCL > WCL in freshly amended soils. TNT in WCL, with "low" relative bioavailability, was least toxic of the five soils tested. TNT toxicity was greatest in the "high" relative bioavailability soils (SSL and PSL). Weathering and aging studies are ongoing.

Toxicity was greatest in TSL and SSL, which have the lowest organic matter, clay content, and pH. KCL and RCL had relatively lower toxicity than TSL and SSL. TNT toxicity was lowest in WCL. The property that distinguishes WCL from the others is organic matter content (OMC). The OMC of WCL is 5.3% compared to 3.3%, 2.6%, 1.4%, and 1.3% for RCL, KCL, TSL, and SSL, respectively. WCL also has the greatest clay content (36%). Organic matter can bind organic chemicals in soil, thereby reducing their bioavailability (USEPA, 2003). Sorption is further enhanced in soils with relatively high clay content. Clay content for WCL, RCL, KCL, SSL, and TSL was 28%, 28%, 28%, 17% and 13%, respectively.

CONCLUSIONS

Soil physical and chemical properties can alter the toxicity of TNT, as evidenced by the different ecotoxicological responses of soil invertebrates exposed to the same TNT concentrations in different types of soil. Organic matter content appears to be the most prominent factor affecting TNT toxicity. Soils with relatively high clay content may also decrease the toxicity of TNT in soil. Such information can be used for environmental compliance for training of Force Objective Soldiers at training facilities that differ significantly in soil type. Environmental compliance may be met, in part, by considering and taking advantage of the specific soil types at a particular training facility when designing and scheduling field training. Therefore, proper training may proceed on schedule with greater efficiency.

REFERENCES

Simini, M., Wentsel, R.S., Checkai, R.T., Phillips, C.T., Chester, N.A., Majors, M.A. and Amos, J.C. (1995). Evaluation of soil toxicity at Joliet army ammunition plant. *Environ. Toxicol. Chem.* 14(4): 623-630.

USEPA. (2003). Ecological Soil Screening Level Guidance. U.S. Environmental Protection Agency. Office of Emergency and Remedial Response. Washington, DC.

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